CHAPTER 10
TRADE-OFF ISSUES

CHAPTER CONTENTS

The Cleaner Technologies Substitutes Assessment's goal is to offer as comprehensive a picture as possible of the relevant factors associated with each of the available clothes cleaning alternatives—the possible environmental and health risks, the costs of mitigating these risks, operating costs, and the level of cleaning performance associated with each alternative. With this information, fabricare professionals can make more informed decisions regarding pollution prevention and the possible advantages and disadvantages associated with alternative approaches for reducing exposures to chemicals used in fabricare processes.

This chapter summarizes much of the information presented throughout the CTSA. Section 10.1 presents a summary of the factors influencing choices in cleaning technology or the type of equipment used within a cleaning technology category. The factors associated with each cleaning process include the following: (1) potential risks, (2) costs, (3) performance characteristics, and (4) other characteristics. Section 10.2 introduces a benefit/cost analysis as a method of assessing alternative options. This section reformulates the summary discussion in Section 10.1 by demonstrating how the factors discussed there can be assessed using a benefit/cost approach. Section 10.2 also presents an assessment of the costs and benefits of alternative cleaning options using a cost-effectiveness approach.

10.1 SUMMARY OF TRADE-OFF FACTORS

In order to implement pollution prevention and possibly reduce exposures and/or risks from the chemicals used in clothes cleaning, clothes cleaners may consider either controlling releases of chemicals from their current technology or switching to an alternative technology. Such decisions involve numerous trade-offs among costs, performance, health and environmental risks related to a particular process, and other factors. These trade-offs are summarized in the following sections.

10.1.1 Potential Health and Environmental Risks

This section summarizes the available information about the potential health, environmental, and other risks associated with the cleaning alternatives discussed in this document. It is important to acknowledge that several components are relevant to an understanding of the risks associated with the chemicals and/or processes used in clothes cleaning. These components are the hazards or effects that may be caused by chemicals and/or processes, and the exposure to those chemicals and/or processes.

Previous chapters of the CTSA on hazard, exposure, and risk describes the risk considerations associated with the covered technologies. It is clear that there is a disparity in the amount of risk-related information available on the various chemicals and processes. In addition, circumstances affecting hazards (e.g., actual detergent formulations) and exposure (e.g., machine type and operating procedures) will vary for specific operations, thus affecting actual risks. Therefore, the consideration of risk factors is best presented by highlighting the most relevant hazard and exposure components. Those populations that are most likely to be highly exposed, and therefore more likely to experience effects of the chemicals and processes, are identified as populations of concern. It is these populations for which exposure reduction is expected to be most relevant. The information on risk considerations should be reviewed with the appropriate regard to the surrounding uncertainties. It is important to understand that a lack of information does not necessarily mean that a chemical with limited information is better or worse than another.

Exhibit 10-1 summarizes the risk considerations for the clothes cleaning technologies covered in the CTSA. These considerations were primarily identified as those resulting in potential health and environmental risks, given the scenarios and assumptions of the hazard, exposure, and risk characterizations in earlier chapters. Therefore, it is likely that not every identified effect associated with a chemical or process is included. Additionally, the reader should understand that these considerations may be less important or may be heightened by the specific characteristics of individual operations.

The risk assessments for the CTSA were conducted at a "screening level" of review, using readily available information and standard analyses for completion. The risk assessments and characterizations should give a rough idea of the array of potential risks to human health and the environment associated with each of the cleaning processes, and should offer a basis for comparison. However, careful interpretation is necessary, given that the extent of uncertainties associated with the type of hazard and exposure data, and the uncertainties associated with each process, differ widely. It is important to recognize that tabular displays, while convenient for organizing information, cannot extract all the details that may be important for each individual's decision.

Drycleaning - PCE

There is a reasonable basis to conclude that there can be a health risk of cancer and some non-cancer effects to workers from the relatively high perchloroethylene (PCE) exposures observed on average in the drycleaning industry. Cancer concerns also extend to residents living in co-location with drycleaning establishments, particularly if they live in such dwellings for several years. The risk indices calculated for this CTSA generally show upper bound excess cancer risks to be high. As expected, cancer risks appear to be higher for residents living above transfer machines due to higher levels of exposure (higher levels of solvent release), although poorly maintained dry-to-dry machines have been documented to potentially cause high exposures.

There can also be a risk of non-cancer effects from PCE to co-located residents. Adults in residences above non-vented dry-to-dry machines appear to have lower exposures. Children, infants, and the elderly, who spend most of their days within the residence, may be at slightly greater risk for both cancer and non-cancer effects due to increased exposure duration. Co-located residents are additionally at risk through a variety of PCE exposures experienced by the general public. Risks experienced by the general population, such as drinking or showering with PCE-contaminated water, would be added to the risks due to co-location.

Given the release estimates developed in the CTSA, it does not appear that there is concern for risk to aquatic species from the majority of drycleaners who send their wastewater effluents to a publicly owned treatment works (POTW).

Exhibit 10-1. Risk Considerations

Chemical Name	Human Health			Aquatic Toxicity	Other Hazardous Properties[b]
	Population	Expected Exposure Route	Effect[a]		
Perchloroethylene	Workers	Inhalation, dermal	Cancer, variety of non-cancer effects including neurotoxicity, kidney and liver damage, and reproductive toxicity.	Medium concern	None identified
	Co-located adults	Inhalation, dermal, ingestion			
	Co-located special populations	Inhalation, ingestion			
	General Population	Inhalation, ingestion			
Hydrocarbon Technologies					
Stoddard solvent (petroleum)	Workers	Inhalation, Dermal	Neurotoxicity, irritation.	High concern	flammable, ignitable
140°F solvent	Workers	Inhalation, Dermal	Assumed to be similar to Stoddard solvent.	High concern	flammable, not ignitable
DF-2000	Workers	Inhalation, Dermal	Assumed to be similar to Stoddard solvent.	High concern	flammable, not ignitable

Exhibit 10-1. Risk Considerations (Cont'd)

Machine Wetcleaning Technology - Example Detergent Component					
Surfactants					
Cellulose gum	Workers	Inhalation, dermal	No significant adverse effects in animal and human studies.	Not predicted	None identified
Cocamidopropyl betaine	Workers	Inhalation, dermal	Potential irritation.	Medium concern	None identified
Ethoxylated sorbitan monodecanoate	Workers	Inhalation, dermal	Little or no skin irritation; may enhance tumor activity of carcinogenic compounds.	Medium concern	None identified
Lauric acid diethanolamide	Workers	Inhalation, dermal	Mild eye irritation.	High concern	None identified
Methyl 2-sulfolaurate, sodium salt	Workers	Inhalation, dermal	No health data found.	Medium concern	None identified
Sodium laureth sulfate	Workers	Inhalation, dermal	Eye, skin irritation.	Medium concern	None identified
Sodium lauryl isethionate	Workers	Inhalation, dermal	Very limited health data, apparently no irritation.	Medium concern	None identified
Surfactant Aids					
Acetic acid	Workers	Inhalation, dermal	Eye injury.	Low concern	None identified
Citric acid and sodium citrate	Workers	Inhalation, dermal	Eye, skin irritation.	Medium concern	None identified
Sodium carbonate	Workers	Inhalation, dermal	Eye and skin irritation; respiratory effects.	Medium concern	None identified

[a] Absence of a specific health effect does not mean that effect may not happen where information is limited on a particular substance.
[b] Flammability based upon National Fire Protection Association ranking of 2 meaning that the chemical must be moderately heated before ignition will occur and that it readily gives off ignitable vapors. Ignitability based upon the Resource Conservation and Recovery Act whereby a chemical is considered ignitable if it is a liquid, other than an aqueous solution, containing less than 24% alcohol by volume and has a flashpoint less than 60° C.

Drycleaning - HC

A major hazard identified for the HC solvents considered in the CTSA is their potential flammability. The National Fire Protection Association (NFPA) gives them a grading of “2” for flammability, indicating that the HC solvents must be moderately heated or exposed to relatively high ambient temperatures before ignition can occur. For comparison, perchloroethylene receives a grade of “0” for flammability, which indicates that it will not burn. Data are not available to evaluate the risks of fire in drycleaning facilities due to use of these HC solvents. However, the risk of fire from their use can be considered greater than the risk of fire due to PCE-based solvents, based on the NFPA’s low flammability ranking for PCE. In addition, the varying flashpoints of the three HC solvents examined suggest that the fire potential is lessened as one employs a higher flashpoint HC solvent. Of the HC chemicals examined in the CTSA, DF-2000 generally has the highest flashpoint, followed by 140°F solvent, and Stoddard solvent.

The health risk conclusions for the HC solvents in the CTSA are based on findings for Stoddard solvent; however, there are no data suitable for drawing conclusions concerning carcinogenic potential. Worker exposures to HC solvents, especially the high-end exposures, are indicative of a concern for non-cancer risk for workers. No data were available on exposures of co-located residents, and therefore, no risk estimates were made. Based on expected releases, there is a low risk of toxicity to aquatic species from the HC solvents.

Machine Wetcleaning

There may be a risk to aquatic organisms from some of the constituents of the machine wetcleaning formulations, dependent on the local stream flow and water treatment conditions. There is no expected health risk to the general public based on low expected exposures to detergents; however, there could be a possible risk to workers of eye and skin irritation from wet process formulations, based upon findings associated with the example detergents.

10.1.2 Federal Regulatory Environment

Professional clothes cleaners are subject to the requirements of many federal air, water, waste management, and occupational health and safety regulations, including the Clean Air Act (CAA); the Clean Water Act (CWA); the Safe Drinking Water Act - Underground Injection Control Regulations (SDWA-UIC); the Resource Conservation and Recovery Act (RCRA); the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA); the Occupational Safety and Health Act (OSH); and the Federal Trade Commission’s Care Labeling Rule. In addition, cities and municipalities have enacted numerous zoning restrictions that may affect all types of fabricare operations. Many localities have adopted some, or all, of the National Fire Protection Association’s standards for drycleaning equipment and operations (NFPA-32). These regulations and requirements can affect the choice of cleaning technology by restricting the use of or adding requirements to the use of certain processes. These restrictions and requirements have the potential to affect costs and liabilities.

Exhibit 10-2 summarizes some federal regulations that relate to fabricare technologies covered in the CTSA. State and other requirements are not included; however, they may have a significant effect on technology choice. Requirements that pertain to the use of spotting chemicals are not covered, but they should not be overlooked because they may affect regulatory compliance activities for fabricare operations.

PCE and HC cleaning are most affected by provisions of federal regulations. Machine wetcleaning currently has fewer requirements that are directly applicable. It is unclear how requirements may change as industry use of these technologies changes. The Care Labeling Rule relates to all cleaning methods, although it does not contain specific requirements for cleaning garments. The rule requires manufacturers to label garments identifying acceptable cleaning methods. Garments that are cleaned in a manner other than that specified by the manufacturer and are subsequently damaged are the responsibility of the cleaner. Manufacturers may cautiously label garments as "dryclean only" (Wentz, 1996; Riggs, 1998). In effect, this may constrain the cleaner interested in avoiding liability from utilizing wetcleaning processes.

Exhibit 10-2. Summary of Federal Regulations Applicable to Fabricare Technologies[a]

Fabricare Option	CAA	CWA	RCRA	CERCLA	OSH	Care Labeling Rule	Other
PCE cleaning	✓	✓	✓	✓	✓	✓	NFPA 32
HC cleaning	✓	✓	✓	✓	✓	✓	NFPA 32
Machine wetcleaning	NA	✓	NA	NA	NA	✓	NA

✓ Indicates that a technology is regulated specifically in statute.
NA Indicates that although the statutes apply to the technology there are no specific regulatory requirements.
[a] The list of regulations covered in this chapter should not be considered exhaustive and may not cover all regulated aspects of the fabricare industry.

10.1.3 Costs

The costs of running a professional clothes cleaning business include rent, basic operating expenses, and equipment. The equipment capacity, equipment type, and location of the facility will also affect the costs and economic viability of a professional cleaning operation. This document has focused on a subset of the costs associated with operating clothes cleaning facilities and a subset of the possible technologies, for which information is available.

The cost components of each of the cleaning options summarized in the CTSA include capital (equipment) cost and the annualized cost of that equipment. In addition, estimates of total annual operating cost, total annual cost (the sum of total annual operating cost and annualized capital cost), and total annual cost per pound of clothes cleaned are provided. Exhibit 10-3 summarizes the process-dependent cost components estimated for selected cleaning technologies covered in the CTSA. Cost figures are presented in constant 1997 dollars in order to allow direct comparisons among the process options. More detailed cost estimates and explanations of how estimates were derived are given in Chapter 7.

In order to reduce exposure to chemicals used or to prevent pollution, cleaners may consider either controlling emissions from the technology they currently use or switching to a different technology. For this reason, the CTSA assesses the costs of PCE and HC process modifications that can reduce exposure. This is intended to provide examples for reducing solvent exposure without changing technologies for cleaners who are unable to change their entire process.

Exhibit 10-3. Summary of Estimated Process-Dependent Cost Components for Selected Fabricare Technologies[a]

Fabricare Technology[b]	Capital Cost of Base Equipment[c]	Capital Cost Total[d]	Annualized Cost of Equipment[e]	Annual Cost Solvent[f]	Annual Energy Cost[g]	Regulatory Compliance Costs[h]	Annual Cost Hazardous Waste[i]
PCE	$38,511	$38,511	$4,228	$1,434	$136	$3,680	$4,594
HC	$37,432	$37,432	$4,110	$2,236	NA	NA	$9,820
Machine Wetcleaning	$11,102	$11,102	$1,219	$763	$788	NA	NA

Exhibit 10-3. Summary of Estimated Process-Dependent Cost Components for Selected Fabricare Technologies (Cont'd)

Fabricare Technology	Annual Cost Filters and Detergent[j]	Annual Cost Maintenance[k]	Total Annual Operating Cost[l]	Total Annual Cost[m]	Total Annual Cost/Pound
PCE	$1,913	$6,000	$14,077	$18,305	$0.34
HC	$1,551	$6,000	$19,607	$23,717	$0.44
Machine Wetcleaning	$3,162	$376	$5,089	$6,308	$0.12

NA means cost category not applicable for technology or that data are not available at this time.

[a] The values include the price of equipment, labor and services directly related to the various drycleaning processes, but exclude costs for pressing, storefront operations, and rent. All values are in 1997 dollars and all calculations assume a 53,333 pound (24,191) annual volume of clothes cleaned per facility. Costs are meant to provide relative comparisons and may differ for specific fabricare operations.
[b] Configurations for fabricare technology include: PCE dry-to-dry closed-loop with no carbon adsorber or with door fan and small carbon adsorber (PCE-C), as required by the PCE NESHAP regulation; HC Transfer with Recover dryer and condenser (HC-A2); and Unimac UW30 washer and DTB50 dryer.
[c] List price of 35 pound PCE drycleaning system includes control equipment, distillation unit, and filters; List price 35 to 40 pound HC drycleaning system includes control equipment, filters, and an explosion kit.
[d] Base machine costs (actual or implied) are added to cost of control capital.
[e] Annual cost of drycleaning equipment, annualized using 7% interest and assuming equipment life of 15 years.
[f] PCE solvent cost based on $6.83 per gallon for PCE in 1997 dollars (BLS, 1997; USEPA, 1993) and "mileage" from EPA engineering estimates; HC solvent cost based on $2.24 per gallon for hydrocarbon solvent and "mileage" based on engineering estimates; wetcleaning solvents cost based on $3.06/100 feet^3 for water (BLS, 1997; USEPA, 1993).
[g] All technology energy costs are based (USEPA, 1991) on $0.0764/kWh national average electricity cost (BLS, 1997).
[h] Regulatory compliance costs for PCE are based on 1.84% of total annual revenues of $200,000 (Gottlieb et al., 1997; NCAI, 1998).
[i] Hazardous waste disposal costs for PCE and HC based on $6.94 per gallon disposal cost (Beedle, 1998) and volume calculations from EPA engineering estimates, excluding disposal cost for potentially hazardous spotting chemicals. Hazardous waste associated with PCE-based machines includes filters, distillation residues, and spent carbon. Hazardous waste associated with HC-based machines includes spent cartridge filters and vacuum still bottoms.
[j] Cost includes of cleaning detergents, spotting chemicals, and replacement filters (Hill, Jr., 1994b; USEPA, 1993).
[k] Annual maintenance cost for PCE and HC based on 3.0% of total revenues of $200,000 annually; costs for machine wetcleaning based on 3.39% of total capital costs (Murphy, 1994).
[l] Includes solvent, energy, hazardous waste, filters, detergent, and maintenance costs. The cost of labor, another component of annual operating costs, is omitted due to lack of data.
[m] Includes all operating costs and annual capital costs.

The CTSA considers the estimated process-dependent costs of eight PCE machine configurations and three hydrocarbon machine configurations. These alternatives are developed to provide information useful in making comparisons of the relative costs of the alternatives within a single technology (e.g., PCE). Some alternatives are no longer available (e.g., new PCE transfer machines); however, they are still provided so that individual cleaners using these configurations can compare the costs of changing to another configuration. Exhibit 10-4 presents a summary of estimated process-dependent costs for the PCE machine configurations; Exhibit 10-5 presents a summary of estimated process-dependent costs for the HC machine configurations.

10.1.4 Performance Characteristics

The basic performance goals of all professional clothes cleaning technologies are the same. Any cleaning technology applied to a textile should strive to (1) optimize soil removal by overcoming the physical and chemical forces that bind soils to the textile; (2) transport soils away from the textile through the cleaning medium; (3) preserve and/or restore the original attributes of the textile, including its dimensions, dye character, and overall fabric finish; and (4) be cost-effective to the cleaner. Chapter 6 summarizes the performance tests that have been conducted on alternative cleaning technologies. For several reasons (discussed below), however, it is difficult to rank alternative technologies on cleaning performance, and there is no single industry measure that could be used for such a ranking.

Several factors may affect the performance of a cleaning process, including soil chemistry, textile fiber type, transport medium (aqueous vs. non-aqueous), chemistry of additives (detergents, surfactants), use of spotting agents, and process controls (time, temperature, and mechanical actions). These factors work interactively to provide a range of cleaning abilities for all clothes cleaning processes. In addition, customer perceptions of a “clean” garment will vary due to regional, socioeconomic, and cultural differences. Finally, variations in technology and the knowledge base of operators may also affect the performance of the clothes cleaning process.

Although there is insufficient information to characterize the cleaning performance of each of the cleaning technologies considered in this document, some general comparisons are possible between drycleaning (solvent-based) cleaning processes and wetcleaning (water-based) processes. Drycleaning processes are more effective at dissolving oils and fatty stains (non-polar soils), while wetcleaning processes tend to dissolve sugar, salt, and perspiration (polar stains) with greater success. It is unclear whether particulate soils are better handled by one process type or the other. The cleaning ability of both wet and drycleaning processes may be enhanced with the use of spotting agents, alternative detergents, surfactant additives, and other process modifications (e.g., time, temperature, mechanical action).

These two types of cleaning processes also excel at cleaning different kinds of materials. Drycleaning processes are most effectively used with textiles that contain water-loving (hydrophilic) fibers (such as wool), low-twist yarns, low-count fabrics, and polar colorants. Wetcleaning processes are effective with textiles containing water-hating (hydrophobic) fibers (such as polyester and nylon), high-twist yarns, high-count fabrics, and non-polar colorants.

Exhibit 10-4. Estimated Process-dependent Cost Components of Selected PCE Machine Configurations[a]

Machine Configuration[b]	Capital Cost of Base Equipment[c] (Implied Cost)	Capitol Cost of Retrofit Control Technology[d]	Capital Cost Total[e]	Annualized Cost of Equipment[f]	Annual Cost Solvent[g]	Annual Energy Cost[h]	Regulatory Compliance Costs[i]
Transfer							
Transfer with no CA or RC (PCE-A1)	$19,680	$0	$19,680	$2,161	$4,282	NA	$3,680
Transfer with CA (PCE-A2)	$19,680	$8,121	$27,801	$3,052	$3,203	NA	$3,680
Transfer with RC (PCE-A3)	$19,680	$8,823	$28,503	$3,129	$2,848	NA	$3,680
Dry-to-Dry							
Dry-to-dry with no CA or RC (PCE-B1)	$31,781	$0	$31,781	$3,489	$3,832	$78	$3,680
Dry-to-dry with CA (PCE-B2)	$31,781	$7,477	$39,258	$4,310	$2,425	$94	$3,680
Dry-to-dry converted to closed-loop (PCE-B3)	$31,781	$7,607	$39,388	$4,325	$2,069	$106	$3,680
Dry-to-dry closed-loop with no CA or with door fan and small CA (PCE-C)	$38,511	$0	$38,511	$4,228	$1,434	$136	$3,680
Dry-to-dry closed-loop with unvented integral secondary CA (PCE-D)	$47,475	$0	$47,475	$5,213	$1,216	$186	$3,680

See notes at end of table.

Exhibit 10-4. Estimated Process-Dependent Cost Components of Selected PCE Machine Configurations[a] (Cont'd)

Machine Configuration[b]	Annual Cost Hazardous Waste[j]	Annual Cost Filters and Detergent[k]	Annual Cost Maintenance[l]	Total Annual Operating Cost[m]	Total Annual Cost[n]	Total Annual Cost/pound
Transfer						
Transfer with no CA or RC (PCE-A1)	$4,567	$1,913	$6,000	$16,762	$18,923	$0.35
Transfer with CA (PCE-A2)	$4,629	$1,913	$6,000	$15,745	$18,797	$0.35
Transfer with RC (PCE-A3)	$4,567	$1,913	$6,000	$15,328	$18,457	$0.35
Dry-to-Dry						
Dry-to-dry with no CA or RC (PCE-B1)	$4,567	$1,913	$6,000	$16,390	$19,879	$0.37
Dry-to-dry with CA (PCE-B2)	$4,629	$1,913	$6,000	$15,061	$19,371	$0.36
Dry-to-dry converted to closed-loop (PCE-B3)	$4,567	$1,913	$6,000	$14,655	$18,980	$0.36
Dry-to-dry closed-loop with no CA or with door fan and small CA (PCE-C)	$4,594	$1,913	$6,000	$14,077	$18,305	$0.34
Dry-to-dry closed-loop with unvented integral secondary CA (PCE-D)	$4,594	$1,913	$6,000	$13,909	$19,122	$0.36

NA means Not Available.
[a] The values include the price of equipment, labor, and services directly related to the various dry cleaning processes but exclude costs for pressing, storefront operations, and rent. All values are in 1997 dollars and all calculations assume a 53,333 pound (24,191 kilogram) annual volume of clothes cleaned per facility.
[b] CA - carbon adsorber; RC - refrigerated condenser
[c] Average of list prices of 35 pound drycleaning machine or system with control equipment as shown. Price includes distillation unit and filters where applicable. Base technology prices are shown for the relevant, less controlled dry cleaning equipment system on which the retrofit control equipment is mounted.
[d] Average of list prices for retrofitting control technology.
[e] Base machine costs (actual or implied) are added to cost of control capital.
[f] Annual cost of dry cleaning equipment, annualized using 7% interest and assuming equipment life of 15 years.
[g] Based on $6.83 per gallon for PCE in 1997 dollars (BLS, 1997; USEPA, 1993) and "mileage" from USEPA engineering estimates.
[h] Based on (USEPA, 1991) and $0.0764/kWh national average electricity cost (BLS, 1997).
[i] Based on 1.84% of total annual revenues of $200,000 (Gottlieb, 1997; NCAI, 1998).
[j] Based on $6.94 per -gallon PCE hazardous waste disposal cost (Beedle, 1998) and volume calculations from USEPA engineering estimates, excluding disposal
costs for potentially hazardous spotting chemicals. Hazardous waste associated with PCE-based machines includes filters, distillation residues, and spent carbon.
[k] Cost of dry cleaning detergents, spotting chemicals, and replacement filters (USEPA, 1993).
[l] Based on 3.0% of total revenues of $200,000 annually.
[m] Includes solvent, energy, hazardous waste, filters, detergent, and maintenance costs. The cost of labor, another component of annual operating costs, is omitted due to lack of data.
[n] Includes all operating costs and annual capital costs.

Exhibit 10-5. Estimated Process-Dependent Cost Components of Selected Hydrocarbon Solvent Machine Configurations[a]

HC Machine Configuration[b]	Capital Cost of Base Equipment[c] (Implied Cost)	Capital Cost of Retrofit Control Technology[d]	Capital Cost Total[e]	Annualized Cost of Equipment[f]	Annual Cost Solvent[g]	Annual Energy Cost[h]	Annual Cost Hazardous Waste[i]
Transfer - standard dryer (HC-A1)	$27,830	$0	$27,830	$3,056	$4,836	NA	$9,820
Transfer - recovery dryer with RC (HC-A2)	$37,432	$0	$37,432	$4,110	$2,236	NA	$9,820
Dry-to-dry closed-loop with RC (HC-B)	$52,082	$0	$52,082	$5,718	$1,151	$149	$9,820

Exhibit 10-5. Estimated Process-dependent Cost Components of Selected HC Solvent Machine Configurations[a] (Cont'd)

	Annual Regulatory Compliance Cost	Annual Cost Filters and Detergent[j]	Annual Cost Maintenance[k]	Total Annual Operating Cost[l]	Total Annual Cost[m]	Total Annual Cost/pound
Transfer - standard dryer (HC-A1)	NA	$1,551	$6,000	$22,207	$25,263	$0.47
Transfer - recovery dryer with RC (HC-A2)	NA	$1,551	$6,000	$19,607	$23,717	$0.44
Dry-to-dry closed-loop with RC (HC-B)	NA	$1,551	$6,000	$18,671	$24,389	$0.46

NA means Not Available.

[a] The value includes the price of equipment, labor, and services directly related to the various dry cleaning processes but excludes costs for expenses such as pressing, storefront operations, and rent. All values are reported in 1997 dollars and all calculations assume a 53,333 -pound (24,191 kilogram) annual volume of clothes cleaned per facility.

[b] CA - carbon adsorber; RC - refrigerated condenser.

[c] The list price of a 35- to 40 -pound dry cleaning machine (or system) with control equipment as shown. The price includes filters and an explosion kit where applicable.

[d] Average of list prices for retrofitting control technology.

[e] Base machine costs (actual or implied) are added to cost of control capital.

[f] Annual cost of dry cleaning equipment, annualized using 7% interest and assuming equipment life of 15 years.

[g] Based on $2.24 per gallon for HC solvent and "mileage" based on engineering estimates.

[h] Based on $0.0764/kWh national average electricity cost (BLS, 1997). Energy costs estimated to be 10% higher than those for comparable PCE machines (Hill, 1994a). The authors used the energy costs for PCE-C ($136) to calculate this value for HC-B.

[i] Based on $6.94 per gallon hazardous waste disposal cost (Beedle, 1998) and volume calculations from USEPA engineering estimates, excluding disposal cost for potentially hazardous spotting chemicals. Hazardous waste associated with HC-based machines includes spent cartridge filters and vacuum still bottoms. Note that HC solvent wastes may not be considered hazardous waste under RCRA if its flash point is less than 140°F.

[j] Cost of dry cleaning detergents, spotting chemicals, and replacement filters (USEPA, 1993; Hill, 1994b).

[k] Maintenance costs based on 3.0% of annual revenues of $200,000.

[l] Includes solvent, energy, hazardous waste, filters, detergent, and maintenance costs. The cost of labor, another component of annual operating costs, is omitted due to lack of data.

[m] The estimate includes all operating costs and annual capital costs.

The preservation of the original attributes of the textile (the third performance goal) may itself depend on the combination of cleaning process and type of textile being cleaned. Wetcleaning methods tend to cause expansion of natural and cellulose fibers, leading to a loss of strength, wrinkling, color loss, and dimensional change (i.e., shrinkage or stretching). However, textile manufacturers have developed a number of fiber treatments and modifications (resin preparation, shrink prevention preparation, wool felt prevention) that may minimize such cleaning impacts on clothing. Such alterations are not necessarily apparent when synthetic fibers are subjected to similar water-based cleaning methods. Drycleaning methods, however, may not be appropriate for synthetic fibers due to potential for fiber deterioration.

Because different cleaning processes are more effective with certain types of materials and/or certain types of soils, and because the effectiveness of all cleaning processes may be enhanced by certain process modifications, it is difficult to draw any general conclusions concerning the relative performance of the cleaning technologies considered in this document.

10.1.5 Other Factors

There are several other factors that may affect a clothes cleaner’s decision in selecting alternative technologies. These may include consumer issues beyond performance, such as odor in clothing, liability concerns, and the current state and availability of alternatives. These factors can affect the costs faced by the cleaner, customer satisfaction, or ability to select alternatives.

Clothing cleaned with PCE and some HC solvents can have characteristic odors, although the odors are generally expected to be less for HC. The manufacturer of DF-2000 claims that the solvent is odorless (Exxon, 1998). Odor is not a consideration for machine wetcleaning. This factor may affect consumer satisfaction with cleaning technologies and may affect a clothes cleaner’s selection of cleaning solvents.

CERCLA addresses the cleanup of sites contaminated with improperly disposed chemical wastes. Under CERCLA, potentially responsible parties that contribute to chemical contamination of a particular site, regardless of the intent or involvement of that party, are held strictly liable. Many sites with past and present PCE drycleaning operations are already contaminated to levels that will limit future uses of the property. Groundwater contamination is also possible. These liability considerations may affect decisions regarding technology choices.

Other liability concerns could result from worker claims for health effects resulting from chemicals used in clothes cleaning processes or from garment damage resulting from the various cleaning processes. Of particular note is potential liability for garments damaged in wetcleaning processes that are labeled “dryclean only.”

PCE and HC technologies are well established; PCE currently dominates the market. Wetcleaning has been available in the U.S. since 1994 and is not as well known as the drycleaning technologies.

10.1.6 Summary of Trade-Off Considerations

Each of the factors summarized above may affect the technology choices made by clothes cleaners. Cleaners must consider the costs of running an operation, the service they can provide to consumers, and at what cost. Choices may also be limited by regulatory requirements and levels of necessary capital investment. The potential effects of technology choice on the health and well-being of the environment and individuals exposed to the chemicals used in the cleaning process are also important factors. The choice of cleaning technology involves a complex array of decision factors. Those identified and summarized in the CTSA are organized and presented in Exhibit 10-6.

10.2 APPROACHES FOR CONSIDERING TRADE-OFFS

Given the number of trade-off considerations identified in the CTSA and summarized in Exhibit 10-6, choosing a technology that best suits the needs of a clothes cleaner, while balancing cost and performance considerations, along with trying to meet the goals of solvent reduction, pollution prevention, and profit, can be daunting. This section of the CTSA presents approaches that can be used to structure these considerations and assist the business decision maker.

10.2.1 Benefit/Cost Analysis

Social benefit/cost analysis is used by decision makers to systematically evaluate the impacts to society resulting from individual decisions. A social benefit/cost analysis seeks to compare *all* the benefits and *all* the costs of a given action, considering both private and external costs and benefits. Private costs include those affecting the cleaner, and are typically reflected in the firm's balance sheet. In contrast, external costs[1] are those resulting from the business decision and that are imposed on people (or the environment) who are not a party to the decision. Exhibit 10-7 defines a set of terms typically used in benefit/cost analysis.

Benefit/cost criteria could be used by individual cleaners to evaluate their choice of clothes cleaning technologies. A cleaner might ask what effect the choice of a cleaning technology or machine configuration will have on operating costs, compliance costs, liability costs, and insurance premiums (private costs), as well as on cleaning performance and attractiveness to customers (private benefits). It is less likely, however, that the cleaner would be as familiar with the social costs and benefits of decision making. Costs such as the health and environmental risks discussed in the CTSA may not add to the cost of producing clothes cleaning services (other than, perhaps, an increased liability or insurance costs); however, they represent real costs to society.

Therefore, to develop a social benefit/cost analysis of a choice among fabricare processes, the cleaner would consider not only private costs, such as operating costs and regulatory costs, of the different technologies, but also the *external* costs, such as environmental and health effects associated with cleaning services. The considerations summarized in the earlier parts of this chapter (and assessed throughout the CTSA) are the key components of a social benefit/cost analysis. They are presented together in Exhibit 10-8 and are organized as private costs and benefits and known external costs.

[1] A common example of external costs is provided by the electric utility whose emissions are reducing crop yields for the farmer operating downwind. The external costs incurred by the farmer in the form of reduced crop yields are not considered by the utility when deciding how much electricity to produce. The farmer's losses do not appear on the utility's balance sheet.

Exhibit 10-6. An Overview of Alternative Cleaning Technologies' Trade-Off Factors[a]

Characteristic	PCE	HC	Machine Wetcleaning
Health and Environmental Risks	**Health:** Risk of cancer to workers, co-located residents. Risks of non-cancer effects, including potential for developmental and reproductive effects for workers. May be cancer and non-cancer risks to co-located children. **Environmental:** Potential risk to aquatic organisms for effluent not treated by a POTW	**Health:** Risk of neurotoxic effects and skin and eye irritation for workers. **Fire:** Highest for Stoddard solvent, less for 140°F and DF-2000, based on flashpoint. **Environmental:** Potential to contribute to smog and global warming.	**Health:** Risk not evaluated quantitatively. Potential risks of skin and eye irritation for workers. **Environmental:** Potential risk to aquatic organisms from specific detergent component releases.
Costs[b]			
Potential liability costs	Groundwater contamination and worker illness.	Fire damage.	Damaged clothing labeled "Dryclean Only."
Capital costs[c]	$38,511	$37,432	$11,102
Hazardous waste disposal[d]	$4,594	$9,820	NA
Annual operating costs[e]	$14,077	$19,607	$5,089
Total annual costs[f]	$18,305	$23,717	$6,308
Market Considerations			
State of technology	Dominant in market.	Well-established in market; use of some HCs may be limited by local fire codes.	Commercial use since 1994 in U.S.; numerous detergent suppliers.
Consumer Issues			
Odor	Yes	Yes, maybe less for particular HCs	No
Cleaning Performance	Wide range of clothes.	Wide range of clothes.	Wide range of clothes.

NA means cost category not applicable for technology or that data are not available at this time.

[a] Configurations for fabricare technology include: PCE dry-to-dry closed-loop with no carbon adsorber or with door fan and small carbon adsorber (PCE-C), as required by the PCE NESHAP regulation; HC Transfer with Recover dryer and condenser (HC-A2); and Unimac UW30 washer and DTB50 dryer.
[b] The values include the price of equipment and services directly related to the various fabricare cleaning processes, but exclude costs for pressing, storefront operations, and rent. All values are in 1997 dollars and all calculations assume a 53,333 pound (24,191) annual volume of clothes cleaned per facility.
[c] List price of 35-pound PCE drycleaning system includes control equipment, distillation unit, and filters; list price of 35- to 40-pound HC drycleaning system includes control equipment, filters, and an explosion kit.
[d] Hazardous waste disposal costs for PCE and HC based on $6.94-per-gallon disposal cost (Beedle, 1998) and volume calculations from EPA engineering estimates; HC solvent waste may not be considered hazardous waste under the Resource Conservation and Recovery Act. Therefore, this is a high-end estimate. Hazardous waste costs associated with spotting chemicals or certain detergent components are not included.
[e] Includes solvent, energy, hazardous waste, filters, detergent, and maintenance costs. The cost of labor, another component of annual operating costs, is omitted due to lack of data.
[f] Includes all operating costs and annual capital costs.

Exhibit 10-7. Glossary of Benefit/Cost Analysis Terms

Term	Definition
Exposed Population	The number of people in the general public or a specific population group exposed to a substance through dispersion of that substance in the environment. A specific population group could be exposed because of its physical proximity to a manufacturing facility that uses or produces the substance (e.g., residents who live near a facility using a chemical), because it uses the substance or a product containing the substance, or through other means.
Exposed Worker Population	The number of employees in an industry exposed to the chemical, process, and/or technology under consideration. This number may be estimated by market share data, as well as by estimates of the number of facilities and the number of employees in each facility associated with the chemical, process, and/or technology under consideration.
Externality	"The effects of production and consumption activities not directly reflected in the market" (Pindyck and Rubinfeld, 1989)--i.e., not affecting market prices. For example, a cost or benefit experienced by a third party not a part of a market transaction; or an adverse health effect experienced by a consumer unaware of the adverse effects associated with the product he is using or consuming. The term "externality" is a general term which can refer to either *external benefits* or *external costs.*
External Benefits	Benefits of production and consumption of private goods not directly reflected in the market; i.e., not affecting market prices. For example, the market price of landscaping materials does not reflect the benefits enjoyed by the neighbors of homeowners who improve the aesthetic view by landscaping.
External Costs	Costs of production and consumption of private goods not directly reflected in the market—i.e., not affecting market prices. For example, if a steel mill emits waste into a river and the waste poisons the fish in a nearby fishery, the fishery experiences an external cost as a consequence of the steel production. Another example is an adverse health effect experienced by a consumer who is unaware of the adverse effects associated with the product he is using or consuming.
Human Health Benefits	Reduced health risks to workers in an industry or business and/or to the general public; such benefits may, for example, result from an industry switching to less toxic or less hazardous chemicals, processes, and/or technologies. An example would be switching to a less volatile organic compound, thereby lessening worker inhalation exposures.

Exhibit 10-7. Glossary of Benefit/Cost Analysis Terms (Cont'd)

Term	Definition
Human Health Costs	Increased health risks to workers in an industry or business and/or to the general public; such costs may, for example, result from the production, consumption, and disposal of a firm's product. An example is respiratory effects from stack emissions. These costs can be quantified by analyzing the resulting costs of health care and the reduction in life expectancy, as well as the lost wages as a result of being unable to work.
Cost of Illness	The total cost of an illness to society, including (1) total medical costs and (2) the cost of lost productivity resulting from the illness.
Private (Internalized) Costs	The direct costs incurred by industry or consumers in the marketplace. Examples include a firm's cost of raw materials and labor, and a firm's costs of complying with environmental regulations. The private costs associated with a good or service are reflected in market prices.
Social Cost	The total cost to society of an activity. Social costs are the sum of private costs and external costs. In the example of a steel mill that emits waste into a river and the waste poisons fish in a nearby fishery, the social cost of steel production is the sum of all private costs (e.g., raw material and labor costs) and all external costs (e.g., the costs associated with the poisoned fish).
Social Benefit	The total benefit to society of an activity; i.e., the sum of the private benefits and the external benefits associated with that activity. For example, if a new product yields pollution prevention opportunities (e.g., reduced waste in production or consumption of the product), then the total benefit to society of the new product is the sum of the private benefit (value of the product that is reflected in the marketplace) and the external benefit (benefit society receives from reduced waste).
Willingness-to-pay	Willingness-to-pay (WTP) is the measure used for the value an individual places on something, whether it can be purchased in a market or not. If available, estimates of WTP are used in benefits valuation because they encompass the full value of avoiding an adverse health (or environmental) effect, including, for example, the value of avoiding the pain and suffering associated with the health effect. The total cost of an individual's illness, then, is the cost of illness as defined above, plus the individual's WTP to avoid the pain and suffering associated with the illness.

Exhibit 10-8. An Overview of Benefits and Costs of Alternative Cleaning Technologies

Cleaning Technology	Private Benefits	Private Costs		Known External Costs
		Total Annual Cost/Pound Clothes Cleaned	Other Private Costs[a]	
PCE-Based Drycleaning PCE-C dry-to-dry closed loop with no carbon adsorber or with door fan and small carbon adsorber	Cleans a wide range of clothes. Good cleaning performance. Established technology.	$0.34 [Includes: Capital cost; operating cost (solvent, energy, hazardous waste, filters detergent, and maintenance cost)]	Liability for groundwater contamination Costs of worker illnesses Worker liability claims Odor (within work place)	Potential cancer risks to highly exposed individuals that may include workers, co-located residents, and special populations. Potential health risks such as neurotoxicity and kidney effects to highly-exposed individuals that may include workers and co-located residents. Odor.
Hydrocarbon Solvent-Based Drycleaning HC-A2 Transfer with recovery dryer	Cleans a wide range of clothes. Established technology. Good cleaning performance.	$0.44 [Includes: Capital cost; operating cost (solvent, energy, hazardous waste, filters detergent, and maintenance cost)]	Potentially ignitable, which constrains the possible locations and also may require additional safety equipment. Costs of worker illnesses. Odor.	Potentially ignitable and could cause fire injury and damage to person and property. Varies according to particular solvent with lowest ignitability potential expected for DF-2000. Potential health effects to highly exposed individuals that include neurotoxicity, and irritation of the skin and eyes. Odor, less expected for DF-2000.
Machine Wetcleaning Unimac UW30 washer and DTB50 dryer	Cleans a wide range of clothes. No hazardous waste.	$0.12 [Includes: Capital cost; operating cost (solvent, energy, filters, detergent, and maintenance cost)]	Emerging technology (less complete knowledge of operating parameters, producing greater variability in cleaning results, which may disappoint customers). Greater possibility of shrinkage and thus an increased liability for damaged goods. Appropriate for smaller portion of the clothing stream than PCE and HC. Increased liability for damaged goods because wetcleaning a "Dryclean Only" label makes the cleaner liable for damage.	Potential health effects to workers including dermal and eye irritation from contact with the detergent. Potential risk to aquatic organisms from release of detergents.

[a]These private costs were not included in the calculation of total annual cost per pound of clothes cleaned because of the difficulty in monetizing them.

Because of limited information, the private costs and benefits and external costs associated with the various alternative cleaning options are, for the most part, presented qualitatively. They are intended to give only a broad overview of what may be the important benefits and costs of each of these different options. In actual practice, a business decision maker would evaluate the specifics of the operation under consideration (e.g., particular concerns associated with a machine wetcleaning detergent) and attempt to assign monetary value to the trade-off factors to determine the best choice of cleaning processes.

Where quantitative measures are presented, such as in the area of cost, they are most reflective of the comparison of alternatives relative to each other, rather than a measure of actual value. This is because of the assumptions and uncertainties found when developing general characterizations of the technologies, as done in the CTSA. The effect of such a presentation is to show how the social benefit/cost framework can support the decision-making process, and highlight significant factors and considerations for each technology choice. By understanding which factors are significant, and how they are interpreted as costs and benefits, the individual cleaner could use such information as a starting point for developing technology comparisons for a specific operation.

Comparisons of the costs and benefits associated with different process options within the PCE-based drycleaning category and within the petroleum solvent-based drycleaning category are presented later in this section using an alternative decision-making process.

10.2.2 Cost-Effectiveness Analysis

Given the investment required to switch among technologies, it is also useful to examine the trade-offs faced when attempting to reduce exposure to solvents. Therefore, more detailed comparisons of the costs and benefits associated with different release reduction options are presented. It is recognized that solvent release is not necessarily the best measure of exposures and/or risk, particularly for populations such as co-located residents and the general population. However, the uncertainties involved in assessing exposures and risks associated with specific machine configurations preclude the quantitative estimation of risk trade-offs among those configurations.

As an alternative, the cost-effectiveness of the different options (alternative machine configurations) may be used as a means of comparison. Cost-effectiveness is a measure of the efficiency of an option in achieving a desired goal. In this analysis, the desired goal is the reduction of PCE or HC solvent emissions as a surrogate for reducing exposures to solvents and, therefore, the risks associated with those exposures.

10.2.3 Comparison of Alternative PCE-Based Machine Configurations

PCE is the dominant drycleaning solvent used by industry today. It is used in approximately 82% of all commercial drycleaning facilities. Although there are identified health and environmental concerns with PCE, cleaners currently using PCE may not be inclined to change cleaning technologies for a variety of reasons. They might, however, be willing to make changes to their current PCE technologies that may serve to prevent pollution by reducing releases, thereby potentially reducing exposures. Various modifications of the basic technology are expected to achieve different degrees of reduction in the release of PCE. The CTSA recognizes that release reduction may not be the best surrogate for exposure reduction. However, release reduction is used as a proxy for exposure reduction for illustrative purposes. The costs associated with these variants on the basic PCE-based drycleaning technology are also expected to differ across technologies. This subsection presents a comparison of some of the costs and benefits of eight different variants on the basic PCE-based drycleaning technology.

Exhibit 10-9 summarizes the solvent releases, performance characteristics, and cost characteristics, including capital and operating costs, of several PCE drycleaning machine configurations, and presents qualitative information on potential health and ecological risks using the solvent release volume as an indicator for exposure and risk. The estimated solvent use per year and a relative ranking of solvent mileage is provided for each of the eight PCE drycleaning machine configurations. Estimated solvent releases are also detailed along with information regarding maintenance, capital, operating, and total annual costs. Other issues, such as garment cleanliness and damage, may be considered performance issues in the drycleaning industry, but are not evaluated and are not expected to vary significantly across machine configurations.

Based on the model facility[2] (see Chapters 4 and 7), the PCE closed-loop dry-to-dry machine with unvented integral secondary controls (Option PCE-D) uses the least solvent and has the lowest emissions of the PCE options considered. Solvent usage can be measured in terms of mileage, the number of pounds of clothes cleaned per volume of unrecovered solvent. Exhibit 10-9 ranks mileage, with one being the best and eight the worst. Option PCE-D has the best solvent mileage and Option PCE-A1, a transfer machine with no vent control, has the worst. Therefore, replacing a PCE transfer machine with Option PCE-D, a PCE dry-to-dry closed-loop machine with integrated unvented secondary controls, decreases both PCE use and releases to air by 449 gallons per year while increasing the total wastewater and total hazardous waste volumes (the latter only slightly).

Along with all other dry-to-dry options, Option PCE-D is expected to result in less exposure to PCE to the extent that releases are indicative of exposure. This implies that risks to human health are probably lessened with dry-to-dry technologies when compared with the uncontrolled transfer machine option (PCE-A1). Option PCE-D is also expected to result in lower risks to aquatic life relative to those posed by Option PCE-A1. Overall costs do increase somewhat in going from Option PCE-A1 ($18,923) to PCE-D ($19,122). A more important comparison of costs is the difference between PCE-B1 ($19,879) and PCE-D ($19,122). The slight cost difference indicates a financially positive incentive for fabricare

[2]The model facility processes 53,333 pounds of clothes per year and operates six days a week for 52 weeks a year.

Exhibit 10-9. Estimated Release Reduction Performance and Cost Characteristics of PCE Drycleaning Machine Configurations

Release Reduction Performance and Cost Characteristics	PCE-A1 Transfer No Control	PCE-A2 Transfer with CA Vent Control	PCE-A3 Transfer with RC Vent Control	PCE-B1 Dry-to-Dry with no Control	PCE-B2 Dry-to-Dry with CA Vent Control
Total PCE Solvent Use (gallon/year)	627	469	417	561	355
Solvent Mileage Rank Best = 1 Worst = 8	8	6	5	7	4
Solvent Releases (gallon/year)	627	469	417	561	355
PCE to air	501	342	290	434	228
PCE to water (total wastewater)	0.007 (75)	0.1 (1500)	0.014 (150)	0.007 (75)	0.1 (1,500)
PCE in hazardous waste (total hazardous waste)	127 (658)	127 (667)	127 (658)	127 (658)	127 (667)
Relative Health Risks	High	High	High	High	Medium
Relative Risks to Aquatic Life	Low	Low	Low	Low	Low
Required Control Device Maintenance	NA	Low	High	Low	High
Impact of Poor Control Device Maintenance	NA	Increased PCE Use	Increased PCE Use	NA	Increased PCE Use
Capital Costs[b]	$19,680	$27,801	$28,503	$31,781	$39,258
Annual Operating Costs[c]	$16,762	$15,745	$15,328	$16,390	$15,061
Total Annual Costs[d]	$18,923	$18,797	$18,457	$19,879	$19,371

See Notes at End of Exhibit.

Exhibit 10-9. Estimated Release Reduction Performance and Cost Characteristics of PCE Drycleaning Machine Configurations (Cont'd)

Release Reduction Performance and Cost Characteristics	PCE-B3 D-t-D Converted to Closed Loop	PCE-C D-t-D C-L with No CA or With Small CA and Door Fan	PCE-D D-t-D C-L with Unvented Integral Secondary CA
Total PCE Solvent Use (gallon/year)	303	210	178
Solvent Mileage Rank Best = 1 Worst = 8	3	2	1
Solvent Releases (gallon/year)	303	210	178
PCE to air	176	83	51
PCE to water (total wastewater)	0.014 (150)	0.0014 (150)	0.0014 (150)
PCE in hazardous waste (total hazardous waste)	127 (658)	127 (662)	127 (662)
Relative Health Risks	Medium	Low	Low
Relative Risks to Aquatic Life	Low	Low	Low
Required Control Device Maintenance	Low	Low	Medium
Impact of Poor Control Device Maintenance	Increased PCE Use	Machine Failure	Machine Failure; Increased PCE Use
Capital Costs[b]	$39,388	$38,511	$47,475
Annual Operating Costs[c]	$14,655	$14,077	$13,909
Total Annual Costs[d]	$18,980	$18,305	$19,122

NA means cost category not applicable for technology or that data are not available at this time.

[a] Based on New York State Monitoring Data.
[b] List price of 35-pound PCE drycleaning system includes control equipment, distillation unit, and filters.
[c] Includes solvent, energy, hazardous waste, filters, detergent, and maintenance costs. The cost of labor, another component of annual operating costs, is omitted due to lack of data.
[d] Includes all operating costs and annual capital costs.

professionals to use the maximum available control technology when converting transfer equipment. More detailed information on the risks of the options and the types of costs associated with each is described in Chapters 5 and 7.

Since benefit/cost analysis is not entirely possible in the CTSA because of the lack of quantified benefits, cost effectiveness can be used as an approach for comparing the eight PCE options. The cost-effectiveness of an option is a measure of its efficiency in achieving a desired goal. In this analysis, the options are the 8 PCE machine configurations, and the desired goal is the reduction of PCE emissions as a surrogate for reducing exposures to solvents and, quite likely, the risks associated with those exposures.

Exhibit 10-10 compares the cost effectiveness of the three PCE transfer machine options in controlling PCE releases. Compared to the baseline technology option, a transfer machine with no vent control (PCE-A1), the transfer control options (PCE-A2 and PCE-A3) both have lower total annual costs, as well as lower solvent releases per year. Each of these alternatives therefore results in a *cost-savings* per gallon of solvent emissions controlled. Therefore, instead of the cost per gallon of emissions reduced, the number of gallons of emissions reduced per dollar saved is used as the measure of cost effectiveness. Each bar in Exhibit 10-10 represents the gallons of solvent emissions reduced per dollar saved when a technology option is compared with the baseline option (PCE-A1). For example, there is a 0.45 gallon reduction in PCE emissions for every dollar saved by switching from a transfer machine with no vent control (PCE-A1) to one with carbon adsorber vent control (Option PCE-A3). This figure is derived by taking the difference in the total annual number of gallons of solvent released, 210, and dividing by the savings in total annual cost resulting from moving from Option PCE-A1 to Option PCE-A3, $466. Compared to a baseline transfer machine with no vent control (Option PCE-A1), all additional transfer control options have less initial capital cost. These options reduce solvent usage on an annual basis, as well as having a lower initial capital cost for retrofitting existing transfer equipment. It is also clear from Exhibit 10-10 that retrofitting a transfer machine with a carbon adsorber (PCE-A2) is the most cost-effective option, using the above definition of cost-effectiveness, within this PCE technology category.

Similarly, Exhibit 10-11 compares the cost-effectiveness of the five PCE dry-to-dry machine options in controlling PCE releases. As with the comparison of transfer options, the alternative dry-to-dry options (PCE-B2, PCE-B3, PCE-C, and PCE-D) all have both lower total annual cost and lower solvent releases (in gallons/year) than the baseline technology option (dry-to-dry with no control, option PCE-B1) with which they are being compared. Each bar in Exhibit 10-11 represents the gallons of solvent emissions reduced per dollar saved when a technology option is compared with the baseline emissions from a dry-to-dry machine with no carbon adsorber or refrigerated condenser control (Option PCE-B1). The dry-to-dry closed-loop machine with unvented integral secondary carbon adsorber (PCE-D) appears to be the most cost-effective option, using the above definition, followed by PCE-B2 (carbon adsorber vent control). PCE-B3 (dry-to-dry machine converted to closed-loop controls) and PCE-C (closed-loop with no carbon adsorber or with door fan and small carbon adsorber) seem to have the smallest reductions in emissions per dollar saved.

This presentation illustrates the most cost-effective way to reduce emissions, given the assumptions made in the analysis. It does not, however, present the complete benefits derived from that reduction. These may include reduced health risk to workers, customers, and nearby residents, as well as reduced potential liability from waste disposal.

Exhibit 10-10. Estimated Cost Effectiveness of PCE Transfer Drycleaning Alternatives Compared to PCE Transfer with No Vent Control (PCE-A1)

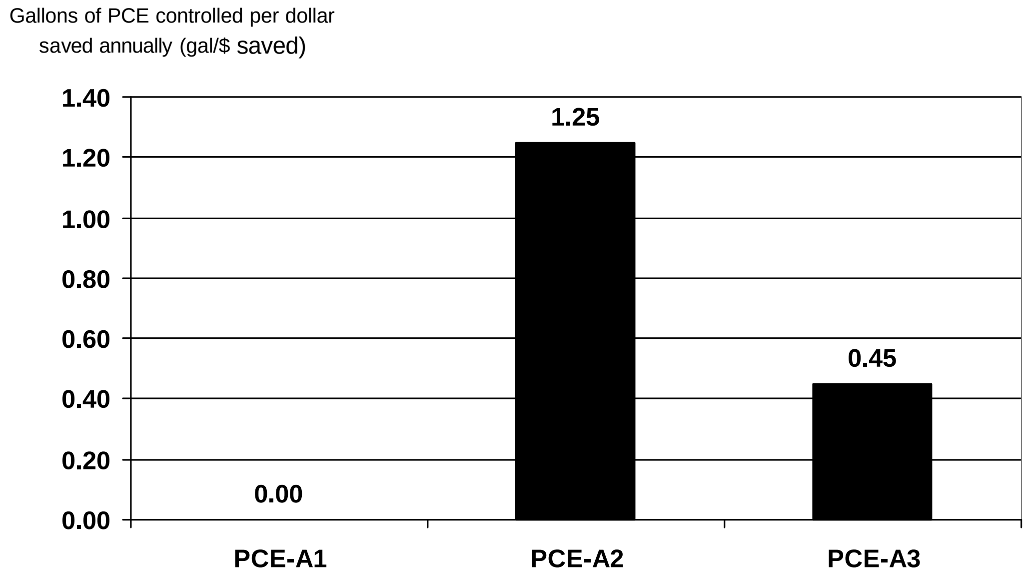
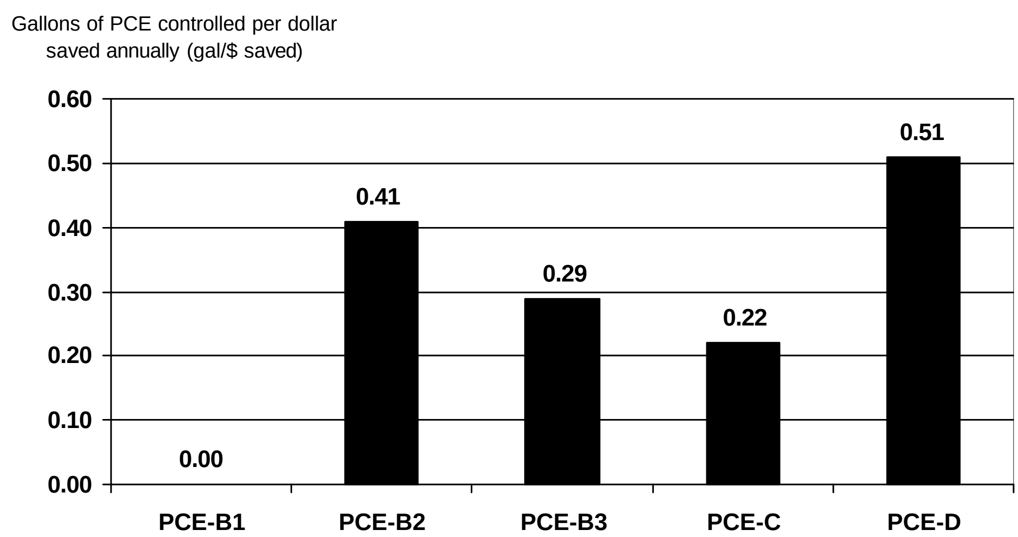


Exhibit 10-11. Estimated Cost Effectiveness of PCE Dry-to-Dry Cleaning Alternatives Compared to PCE Dry-to-Dry with No Vent Control (PCE-B1)



10.2.4 A Comparison of Alternative Hydrocarbon Solvent-Based Technologies

Risks, Release Reduction Performance, and Cost Characteristics

HC solvents dominated the drycleaning market in the United States in the 1950s, but their use has gradually declined, partly due to concerns of fire and explosion hazards. The NFPA classifies drycleaners by the petroleum solvent (HC) they use, and solvents by their flashpoint. Class II solvents (flashpoints between 100°F and 140°F, often termed Stoddard solvent) and Class IIIA solvents (flashpoints 140°F and above, often termed 140°F solvent) are the primary solvents used in this industry. NFPA codes limit Class II solvents to use in free-standing buildings (i.e, not in multi-dwelling buildings) only.

Exhibit 10-12 summarizes the solvent releases, performance characteristics, and cost characteristics, including capital and operating costs, of HC drycleaning machine configurations, as well as both health and environmental risks using solvent releases as a surrogate for potential risk. The estimated solvent use per year and a relative ranking of solvent mileage is provided for each of three HC drycleaning machine types. Solvent releases also are detailed as well as cost information regarding maintenance and energy use. Other issues, such as garment cleanliness and damage, which may be considered performance issues in the drycleaning industry, are not evaluated, and are not expected to vary significantly across machine configurations.

Based on the model facility[3] (see Chapters 4 and 7), the use of a closed-loop dry-to-dry machine with a refrigerated condenser (HC-B) shows a reduction in solvent consumption compared to a transfer machine with conventional dryer (Option HC-A1). This higher mileage decreases solvent air emissions and lowers the corresponding exposures and health risks. Replacing an uncontrolled HC transfer machine with a dry-to-dry closed-loop machine with a refrigerated condenser decreases both the HC solvent use and the release to workplace air by 1,645 gallons per year, although wastewater releases increase by 414 gallons.

Cost-Effectiveness

Reduction in solvent losses may offset the cost of control technology in some HC solvent options. Exhibit 10-13 compares the cost effectiveness of alternative hydrocarbon cleaning technologies in controlling HC) solvent releases. As was the case in the two PCE-based cost-effectiveness comparisons (Exhibits 10-10 and 10-11), the alternatives have both lower total annual cost and lower solvent releases (in gallons/year) than the baseline technology option (HC-A1). Each bar therefore represents the gallons of solvent emissions reduced per dollar saved when a technology option is compared with the baseline option, a transfer machine with standard dryer (Option HC-A1). For example, there is a 1.88 gallon reduction in PCE emissions for every dollar saved by switching to Option HC-B. This measure of cost effectiveness is calculated by dividing the difference in the number of gallons of HC released (1,645) by the savings in total annual cost in moving from Option HC-A1 to Option HC-B ($874). As shown in Exhibit 10-13, Option HC-B is the most cost-effective hydrocarbon option considered, using the above measure of cost-effectiveness.

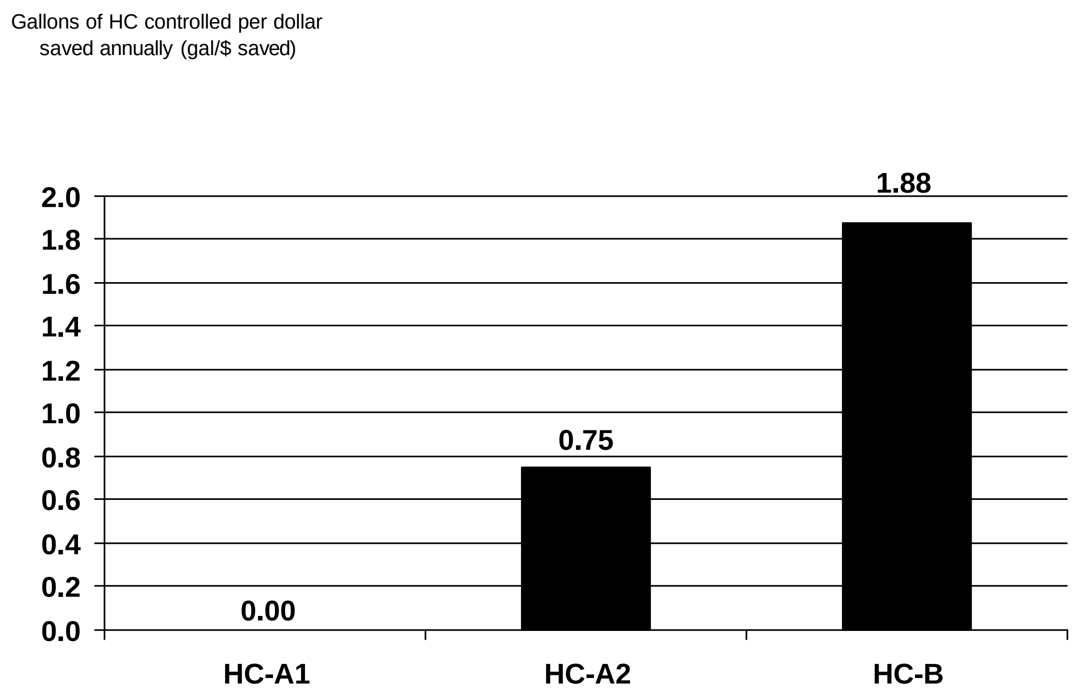
[3] The model facility processes 53,333 pounds of clothes per year operating six days a week for 52 weeks a year.

Exhibit 10-12. Estimated Release Reduction, Performance, and Cost Characteristics of HC Drycleaning Machine Configurations[a]

Release Reduction Performance and Cost Characteristics	HC-A1 Transfer with Conventional Dryer	HC-A2 Transfer with Recovery Dryer	HC-B Dry-to-Dry with Condenser
Total Solvent Use (gal/year)	2,159	998	514
Solvent Mileage Rank (Best = 1; Worst = 3)	3	2	1
Solvent Releases (gal/year)	2,159	998	514
HC to air	1,839	678	194
HC in wastewater (total wastewater)	5×10^{-6} (415)	1×10^{-5} (829)	1×10^{-5} (829)
HC in solid waste (total solid waste)	320 (1,415)	320 (1,415)	320 (1,415)
Relative Health Risks	High	Medium-High	Low
Relative Environmental Risks	High	Medium-High	Low
Degree of Required Maintenance	NA	Low	Low
Impact of Poor Maintenance	NA	Increased HC Use	Machine Failure
Capital Costs[b]	$27,830	$37,432	$52,082
Annual Operating Costs[c]	$22,207	$19,607	$18,671
Total Annual Costs[d]	$25,263	$23,717	$24,389

NA means data are not available at this time.
[a] The value includes the price of equipment and services directly related to the various drycleaning processes, but excludes costs for expenses such as pressing, storefront operations, and rent. All values are reported in 1997 dollars and all calculations assume a 53,333-pound (24,191 kg) annual volume of clothes cleaned per facility.
[b] The list price of a 35- to 40-pound drycleaning machine (or system) with control equipment as shown. The price includes filters and an explosion kit where applicable.
[c] The estimate includes solvent, energy, hazardous waste, filters, detergent, and maintenance costs. The cost of labor, another component of annual operating costs, is omitted due to lack of data.
[d] The estimate includes all operating costs and annual capital costs.

Exhibit 10-13. Estimated Cost Effectiveness of HC Cleaning Alternatives Compared to HC Transfer with Standard Dryer



This presentation identifies the most cost-effective way to reduce emissions, given the assumptions made in this analysis. It does not, however, present the complete benefits that are derived from that reduction. These may include reduced health risk to workers, customers, and nearby residents, as well as reduced potential liability from waste disposal.

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